TOTB 2023

Older Paper

Answers

Question	Mark
Section A	
10	
11	
12	
TOTAL	

SECTION A General chemistry knowledge

1. Give the number of protons, neutrons and electrons in an atom of $^{27}_{13}Al$. [1]

protons 13 neutrons 14 electrons 13

2. Chlorine exists as two isotopes $^{35}_{17}Cl$ and $^{37}_{17}Cl$.

The relative atomic mass of naturally occurring chlorine is 35.5.

Give the ratio of chlorine-35 : chlorine-37 atoms in naturally occurring chlorine. [1]

3 : 1

3. Calculate the relative formula mass of $Mg(OH)_2$ [1]

Relative atomic masses: Mg = 24; O = 16; H = 1

58

4. Which **two** words can be used to describe CO_2? [1]

alloy **compound** **element** **molecule**

5. Which element forms an ionic compound with potassium?

Circle **one** answer.

Mg **Si** **S** **Ar** [1]

6. Name the best separating technique to obtain the solute from a solution. [1]

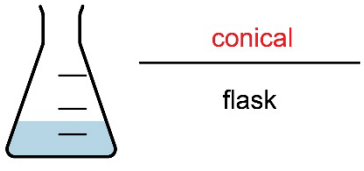
Evaporation

7. Give the chemical symbol of the element named from the Greek word for sun. He [1]

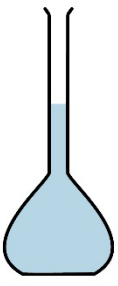
8. What is the name given to a reaction where energy is transferred to the surroundings? [1]

exothermic

9. The image shows two different types of flask. Complete the names of each one. [2]



conical flask



volumetric flask

Spelling must be correct

SECTION B Questions linked to this year's theme of Sustainable Energy

10. This question is about the origin of the UK's energy supply.

The UK obtains its energy from a mixture of fossil fuels and other energy sources including sustainable sources.

An energy source can be described as sustainable if its use today does not impact negatively on the lives of people in the future.

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Table 1 shows the sources of energy supplied to the United Kingdom at 10 am on a Friday in October 2022.

Table 1

		Energy in Gigawatts, GW
Fossil fuels	Coal	0
	Oil	0
	Gas	12.98
Sustainable sources	Solar photovoltaic	0.43
	Wind	15.37
	Hydroelectric	0.54
Other sources	Nuclear	4.63
	Biomass	0.72
	Other	0.23
	TOTAL	**34.90**

Data taken from https://grid.iamkate.com/

a. Calculate the percentage of the total energy that was supplied from;

i. fossil fuels [1]

(12.98 / 34.90) × 100 = **37.2%** _____

_____

ii. sustainable sources [2]

M1 Total from sustainable sources = 0.43 + 15.37 + 0.54 = 16.34 GW _____

M2 As a percentage of total = (16.34 / 34.90) × 100 = **46.8%** _____

b. Fossil fuels release carbon dioxide when they combust.

Carbon dioxide is a greenhouse gas.

Greenhouse gases maintain temperatures on Earth.

i. Describe how carbon dioxide helps to maintain temperatures on Earth. [3]

M1 (Short wave) radiation from the sun passes through the greenhouse gases to Earth

M2 Some energy is absorbed by Earth's surface and rest is reflected (as longer wavelength / IR radiation)

M3 Carbon dioxide / greenhouse gases absorb (some of longer wavelength / IR) radiation trapping it.

Increased levels of carbon dioxide in the atmosphere is linked to rising average global temperatures on Earth.

ii. Give **one** impact of increased global temperatures. [1]

Any one from list below or other correct answer;

Rising sea levels

Polar ice caps melting

Extreme weather

Changes to natural habitats affecting ecosystems

[Total: 7 marks]

11. This question is about energy storage.

Many sustainable sources of energy such as wind turbines and solar panels only generate power if the wind is blowing or the sun is shining.

The ability to store generated energy so that the energy can be used when needed is important.

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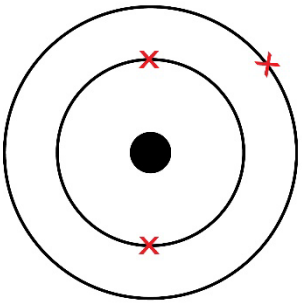
This question is about different methods scientists have developed for storing energy.

One way to store the energy produced is in rechargeable batteries.

a. The most common rechargeable batteries contain lithium.

i. Complete **Figure 1** to show the electronic structure of a lithium **atom**. [1]

Figure 1



ii. Batteries store energy

Energy is then transferred to portable devices when batteries are discharged.

When a lithium battery is discharged, the lithium atoms form lithium ions.

The equation for the reaction is:

$$Li \rightarrow Li^{+} + 1e^{-}$$

Explain if the lithium is oxidised or reduced in this reaction. [1]

Oxidised because the lithium atom loses electrons

(Must include the reason)

b. Researchers are developing a new type of battery that contains calcium.

i. Complete the half equation to give the charge on the calcium ion formed. [1]

$$Ca \rightarrow Ca^{2+} + 2e-$$

ii. Calcium ions are viewed as preferable for batteries to lithium ions.

Suggest why batteries containing calcium ions could store more energy than batteries using lithium ions. [1]

Each atom of calcium releases two electrons / calcium ions have double the charge compared to lithium ions.

An alternative method of energy storage system is to use **hydrogen**.

The energy generated from the sustainable sources is initially used to electrolyse water.

During **electrolysis** water is broken down into hydrogen and oxygen using electricity.

The equation for the reaction is:

$$2H_2O \rightarrow 2H_2 + O_2$$

c. i. Write two half equations to represent the reactions that occur at the positive and negative electrode during the electrolysis of water.

Use e- to represent an electron. [2]

Positive electrode $4OH- \rightarrow O_2 + 2H_2O + 4e-$

Negative electrode $2H^+ + 2e- \rightarrow H_2$

ii. Show how the two half equations combine to give the overall equation for the electrolysis of water. [1]

$4OH- \rightarrow O_2 + 2H_2O + 4e-$

$4H^+ + 4e- \rightarrow 2H_2$

Combined, $4OH- + 4H^+ + 4e- \rightarrow O_2 + 2H_2O + 4e- + 2H_2$

Cancelling $2H_2O$ and 4e- from both sides becomes;

$2H_2O \rightarrow O_2 + 2H_2$

The hydrogen produced by electrolysis is then stored and used as a fuel when needed.

[Total: 7 marks]

12. This question is about Biogas.

Biogas is a renewable fuel produced by the breakdown of organic matter such as food scraps and animal waste.

Biogas consists mainly of methane and carbon dioxide.

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a. Methane is a **hydrocarbon**. What is a hydrocarbon?

A molecule that contains carbon and hydrogen only (must give some indication that it only contains these elements)

To be used as a replacement for natural gas for cooking and heating the biogas needs to be purified.

b. One way to remove the **carbon dioxide** from the mixture of methane and carbon dioxide is by passing the biogas through a solution of sodium hydroxide, NaOH.

Sodium carbonate Na_2CO_3 and water are produced.

Write a balanced symbol equation for the reaction.

Include state symbols. [2]

$CO_2(g) + 2NaOH(aq) \rightarrow Na_2CO_3(aq) + H_2O(l)$

M1 Balanced equation

M2 Correct state symbols

The biogas also includes small quantities of **hydrogen sulfide, H_2S**.

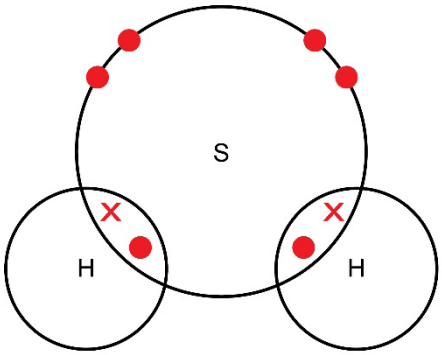
a. i. Hydrogen sulfide is a simple molecule.

Complete **Figure 2** to show a dot and cross diagram for a hydrogen sulfide molecule.

Show the outer electrons only.

Use dots (•) and crosses (×) to represent the electrons. [2]

Figure 2



M1 Shared pair in each overlap

M2 4 non-bonding electrons on S

The hydrogen sulfide is removed by passing the biogas over an absorbent iron sponge.

The iron sponge consists of wood shavings soaked with hydrated iron oxide, $Fe_2O_3 \cdot H_2O$.

The hydrogen sulfide reacts with the iron oxide to produce iron sulfide, Fe_2S_3.

d. The equation for the reaction is:

$$2\ Fe_2O_3 \cdot H_2O + 6H_2S \rightarrow 2\ Fe_2S_3 + 8H_2O$$

The equation is partially balanced.

Complete the balancing by adding numbers where indicated with _____ . [1]

The iron oxide can be regenerated by exposing the iron sulfide to air.

The equation for the reaction is:

$$2Fe_2S_3 + 3O_2 \rightarrow 2Fe_2O_3 + 6S$$

e. Calculate the mass of sulfur produced from the reaction of 128 g of iron sulfide with an excess of oxygen.

Relative atomic masses: Fe = 56; S = 32; O = 16 [3]

Method 1

M1 M_r Fe_2S_3 = (2 × 56) + (3 × 32) = 208

M2 n(Fe_2S_3) = 128 / 208 = 0.6153 mol

n(S) = 0.6153 × 3 = 1.846 mol *Allow ecf marks for M2 and M3*

M3 mass sulfur = 1.846 mol × 32 = **59.1 g**

Method 2

M1 M_r Fe_2S_3 = (2 × 56) + (3 × 32) = 208

M2 Indication that (2 × 208) = 416 g Fe_2S_3 produces (6 × 32) = 192 g S

M3 Therefore 128 g of Fe_2S_3 gives (128 / 416) × 192 = **59.1 g**

f. Once purified the methane can be used as a fuel.

Methane can undergo a combustion reaction.

Figure 3 shows the displayed structures of the reactants and the products.

Figure 3

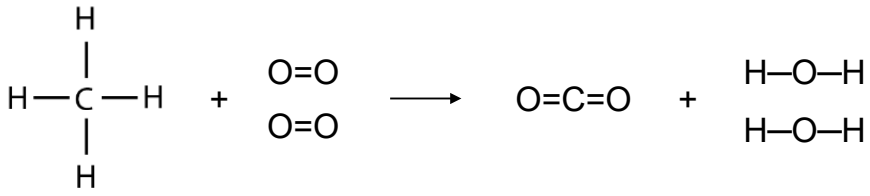


Table 2 shows the bond energies.

Table 2

Bond	Bond energy in kJ/mol
C—H	413
O=O	498
C=O	805
O—H	464

Calculate the overall energy change for the reaction. [3]

Bonds broken

4 × C—H = 1652

2 × O=O = 996

Total energy in = **2648 (M1)**

Bonds made

2 × C=O = 1610

4 × O—H = 1856

Total energy out = **3466 (M2)**

Energy released = 3466 – 2648 = **818 kJ/mol**

Ignore minus sign / Allow ecf marks of incorrect total energy in and or out

Award 3 marks for correct final value without working

g. The torch at the 2008 Beijing Olympics was fuelled by methane produced from biogas.

The torch consumed 6000 m^3 of methane per hour and was kept alight for 16 days.

i. Calculate the total volume of methane burnt during the Beijing Olympics. [1]

6000 × 24 × 16 = **2 304 000 m^3**

ii. Calculate the total mass in kg of methane burnt during the Olympic games.

Assume the volume of one mole of gas is 24 dm^3. [3]

Relative atomic masses: C = 12; O = 16

M1 2 304 000 × 1000 = **2 304 000 000 dm^3** or **2.304×10^9 dm^3** or

M1 24 dm^3 = 0.024 m^3

M2 $n(CH_4)$ = 2 304 000 000 / 24 **= 96 000 000 mol** or **9.6×10^7 mol**

M3 mass CH_4 = 96 000 000 mol × 16 g/mol = 1 536 000 000 g

= 1 536 000 kg

Allow ecf from incorrect mol of methane